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Agreement between self-reported and measured height, weight and body mass index in old age—a longitudinal study with 20 years of follow-up

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Abstract

Background: self-reported body mass index (BMI) based on self-reported height and weight is a widely used measure of adiposity in epidemiological research. Knowledge about the accuracy of these measures in late life is scarce.
Objective: the study aimed to evaluate the accuracy and changes in accuracy of self-reported height, weight and BMI calculated from self-reported height and weight in late life.
Design: a longitudinal population-based study with five times of follow-up was conducted.
Participants: seven hundred seventy-four community-living men and women, aged 40–88 at baseline (mean age 63.9), included in The Swedish Adoption/Twin Study of Aging.
Methods: participants self-reported their height and weight in a questionnaire, and height and weight were measured by experienced research nurses at an in-person testing five times during a 20-year period. BMI was calculated as weight (kilogramme)/height (metre)^2.
Results: latent growth curve modelling showed an increase in the mean difference between self-reported and measured values over time for height (0.038 cm/year) and BMI (0.016 kg/m^2/year), but not for weight.
Conclusions: there is a very small increase in the mean difference between self-reported and measured BMI with ageing, which probably would not affect the results when self-reported BMI is used as a continuous variable in longitudinal studies.

Keywords: *body mass index, height, weight, reliability, elderly*

Introduction

Older people are at a high risk of functional impairment and morbidity. Body mass index (BMI), calculated as kg/m^2, might give an estimation of a person's health status. In the prediction and treatment of various diseases, the trajectory of BMI over time might be of greater clinical value than a single assessment. In epidemiological studies, BMI values are often based on self-reported weight and height (hence forth called self-reported BMI). The accuracy of self-reported BMI in old age has been evaluated by only a few studies, and to our knowledge, the accuracy of self-reported height, weight and BMI has not been previously studied in a longitudinal trial including older people.

The ageing process is accompanied by changes in body composition like decline in stature. It has been proposed that self-reported BMI is less reliable in old age than in younger ages, due to a lack of awareness of these changes [1, 2]. Memory problems might also make self-report less reliable in old age. Others have suggested that self-report is more reliable in old age as there is less social pressure to be thin [3]. Cross-sectional studies have shown that older persons are more likely than younger persons to overestimate their height [1, 2, 4–6]. The results are less clear concerning weight, and there seem to be gender differences. In US second and third National Health and Nutrition Examination Survey [1, 2, 4], women, in general, underestimated their weight, but older women reported their weight more accurately than their younger counterparts [1, 4]. This was also seen among obese older women [2]. Men, on the other hand, overestimated their weight, with the greatest overestimation seen in the oldest age group (80 years and above). In a Swedish study including both men and women, older (65–84 years) overweight and obese persons reported their weight with higher accuracy than younger overweight and obese persons [6].

Despite the inconsistency in the findings for weight, previous studies including various age groups report that self-reported BMI is less reliable in old age compared with self-reported BMI in young age [1, 4, 6–8]. However, due to the cross-sectional design in these studies, it is not possible to draw any conclusions about whether these age differences are due to inter-individual differences like cohort differences or intra-individual changes. The longitudinal Swedish Adoption/Twin Study of Aging (SATSA) provides a unique opportunity to evaluate intra-individual changes in misclassification bias of height, weight and BMI, as since the start of SATSA, height and weight have been self-reported and assessed five times over 20 years.

Methods

Participants

The selection procedures for SATSA have been described in detail elsewhere [9, 10]. In brief, the study sample is a subset from the population-based Swedish Twin Registry [11]. The base population is all twins who indicated that they had been reared apart and a matched sample of twins reared together. At the first in-persons testing (IPT) in 1986–1988, 645 twins participated. Among these, 595 answered a corresponding questionnaire (Q2) in 1987, including questions about height and weight. Since then, these twins have been systematically interviewed every third year (except in 1995, due to lack of funding) by trained research nurses in a primary care facility close to their home. Questionnaires were sent to the participants in the middle of the IPT data collections, which ranged over 2 years. For the present study, five IPTs had matching questionnaire data with self-reported weight and height: IPT 1, 2, 3, 6 and 7. Data were collected between 1986 and 2007. At IPT 2, 3 and 5, a subsample of twins who had answered Q1 and turned 50 years of age since the last IPT were included. In total, data from 774 persons were available for analyses.

Measures

At the first measurement occasion, a trained research nurse measured weight and height in clothing without shoes. In the questionnaires, participants were asked about their weight and height. BMI was calculated as weight in kilogrammes divided by height in metres squared. Clinical dementia diagnoses are available through 2002 from the Study of Dementia in Swedish Twins [12], and at IPT 5 and 6 suspected dementia cases were diagnosed at a consensus conference [13] according to Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R or DSM-IV, 4th ed.) criteria [14]. Selection criteria and diagnostic work-up have been described in detail in previous publications [12, 13]. At the time of analyses dementia diagnoses were not available for IPT7.

Statistics

Irrespective of when a person entered the study, the first measurement occasion was coded as measurement occasion 1. Correlations between self-reported and measured height, weight and BMI were calculated using the Pearson's correlation coefficient. Agreement between BMI categories (cut-off 25 kg/m^2), based on self-reported and measured weight and height, was assessed using the Kappa coefficient, sensitivity and specificity. All analyses mentioned above were performed with the SPSS 16.0 [15], except sensitivity and specificity, which were calculated according to Altman [16].

We employed latent growth curve modelling with a full maximum-likelihood estimation technique [17, 18] to evaluate whether there was an increase in the difference between self-reported and assessed height, weight and BMI over time, employing PROC MIXED in SAS 9.1 [19]. Because we could not assume that the twins were independent of each other, models were adjusted to account for the correlation within twin pairs. To illustrate the trajectory of the accuracy of self-reported BMI over time, the difference between self-reported and assessed BMI was calculated at each time point and plotted with one line per person by age in years.

Results

Sample characteristics

At the first IPT the mean age was 63.9 years (range, 40–88). The mean BMI was 25.6 (range, 16.3–46.1). Less than one percent (0.9%) of the sample had a BMI below 18.5, 47.4% had a BMI between 18.5 and 25, 40.1% had a BMI between 25 and 30 and 11.6% had a BMI above 30. Approximately 60% of the participants were women and the gender distribution was fairly constant over all measurement occasions. During the first four measurement occasions, 72 persons were diagnosed with dementia.

Table 1. Pearson's correlation coefficients between self-reported and measured height, weight and BMI, and the kappa coefficients, sensitivity and specificity for BMI, dichotomised at 25 kg/m²

Measurement occasion	n	Height r	Weight r	BMI r	BMI Kappa	BMI Sensitivity	BMI Specificity
1	774	0.98	0.97	0.94	0.81	0.86	0.95
2	615	0.97	0.98	0.95	0.78	0.84	0.94
3	491	0.98	0.98	0.95	0.79	0.79	0.98
4	273	0.97	0.97	0.93	0.74	0.74	0.96
5	156	0.97	0.97	0.93	0.72	0.72	1.00

Agreement measures between self-reported and assessed height, weight and BMI at each measurement occasion are shown in Table 1. The correlations at each measurement occasion were substantial and significant ($P < 0.001$). The Kappa coefficients of BMI dichotomised at 25 indicated substantial agreement over all measurement occasions, but this agreement declined over time. The sensitivity values were also high, but declined over time. The specificity values were high over all measurement occasions and did not decline over time.

Intra-individual changes over time

Mean values and mean differences between self-reported and measured height, weight and BMI for each of the measurement occasions are shown in Table 2. Height was overestimated by 0.9–1.2 cm. Weight was underestimated by 0.5–1.7 kg. When BMI was self-reported the participants underestimated their BMI by 0.5–1 kg/m^2. Latent growth curve modelling revealed that the difference between self-reported and assessed BMI and height increased significantly with age ($P < 0.001$). For each year the difference between self-reported and measured BMI and height increased by 0.016 kg/m^2 and 0.038 cm, respectively. This means that, over 20 years, there is an increase in misclassification bias of ~0.3 kg/m^2 for BMI (Figure 1) and 0.75 cm for height. There was no statistically significant linear increase in self-report bias for weight. Excluding the extreme outliers (persons reporting their height, weight and/or BMI more than three standard deviations (SD) above or below the mean) did not substantially change the results.

Age and gender differences

The trajectories of change in accuracy of self-reported BMI were compared between persons born before 1920 and persons born in 1920 or later. The results for the younger age group ($n_{ipt1}=334$, $n_{ipt5}=283$) did not substantially differ from the results for the total group. In the older age group ($n_{ipt1}=250$, $n_{ipt5}=14$), there was no significant change in self-reported BMI over time, although the change was in the same direction as for the total sample. As previous studies have reported gender differences, sex was also included in the model. Compared to men, women on average underreported their BMI with 0.3 kg/m^2 ($P < 0.001$) and their weight by 0.4 kg ($P < 0.05$). They also tended to overestimate their height more than men, by 0.3 cm ($P=0.08$). However, there was no significant difference in the slope between men and women, i.e. the difference between men and women with regard to misclassification of height, weight and BMI remained stable over time.

Reliability of BMI related to weight, dementia, and time point of self-report

To measure potential under- and overestimation as a function of BMI, measured BMI at IPT1 was included in the latent growth curve models. For each unit increase in BMI at baseline, the underreporting of weight increased by 0.2 kg ($P < 0.001$), and overestimation of height increased by 0.05 cm ($P < 0.05$). The underestimation of BMI consequently increased by 0.1 kg/m^2 ($P < 0.001$).

A complementary analysis was conducted in which dementia was included in the analysis as a covariate. As dementia diagnoses were only available up to and including IPT6, we first compared the model for first four measurements, with the model including all five measurements. This did not substantially affect the estimates. Dementia status did not significantly affect the reliability of self-reported BMI. Additionally, results did not change substantially when persons diagnosed with dementia during the study period were excluded from the analyses.

The reliability of self-reported BMI in regards to the measurement of height and weight before or after self-report was evaluated at IPT1. In total, 95 persons attended IPT1 3 months or less before the questionnaire phase, and 84 persons attended 3 months or less following completion of the questionnaire. Persons who were assessed after the

Table 2. Means (standard deviations (SD)) and mean differences (SD) for self-reported and measured height, weight and BMI

Time	Height Reported	Height Measured	Height Difference	Weight Reported	Weight Measured	Weight Difference	BMI Reported	BMI Measured	BMI Difference
1	167.3 (9.3)	166.4 (9.7)	0.9 (2.1)	70.1 (12.8)	71.2 (13.4)	−1.0 (3.2)	25.0 (3.5)	25.6 (3.9)	−0.6 (1.3)
2	167.2 (9.7)	166.2 (9.9)	1.0 (2.3)	71.1 (13.7)	71.6 (14.0)	−0.5 (2.7)	25.3 (3.8)	25.8 (4.0)	−0.5 (1.2)
3	166.6 (9.9)	165.6 (10.2)	1.1 (2.1)	71.0 (13.7)	72.2 (14.3)	−1.2 (2.9)	25.5 (3.8)	26.2 (4.2)	−0.8 (1.2)
4	166.2 (9.7)	165.0 (9.6)	1.2 (2.3)	71.2 (13.3)	72.4 (13.8)	−1.2 (3.4)	25.7 (3.9)	26.5 (4.1)	−0.8 (1.5)
5	164.8 (9.9)	163.6 (9.8)	1.2 (2.5)	69.0 (11.8)	70.7 (12.4)	−1.7 (3.1)	25.3 (3.4)	26.4 (3.7)	−1.0 (1.3)

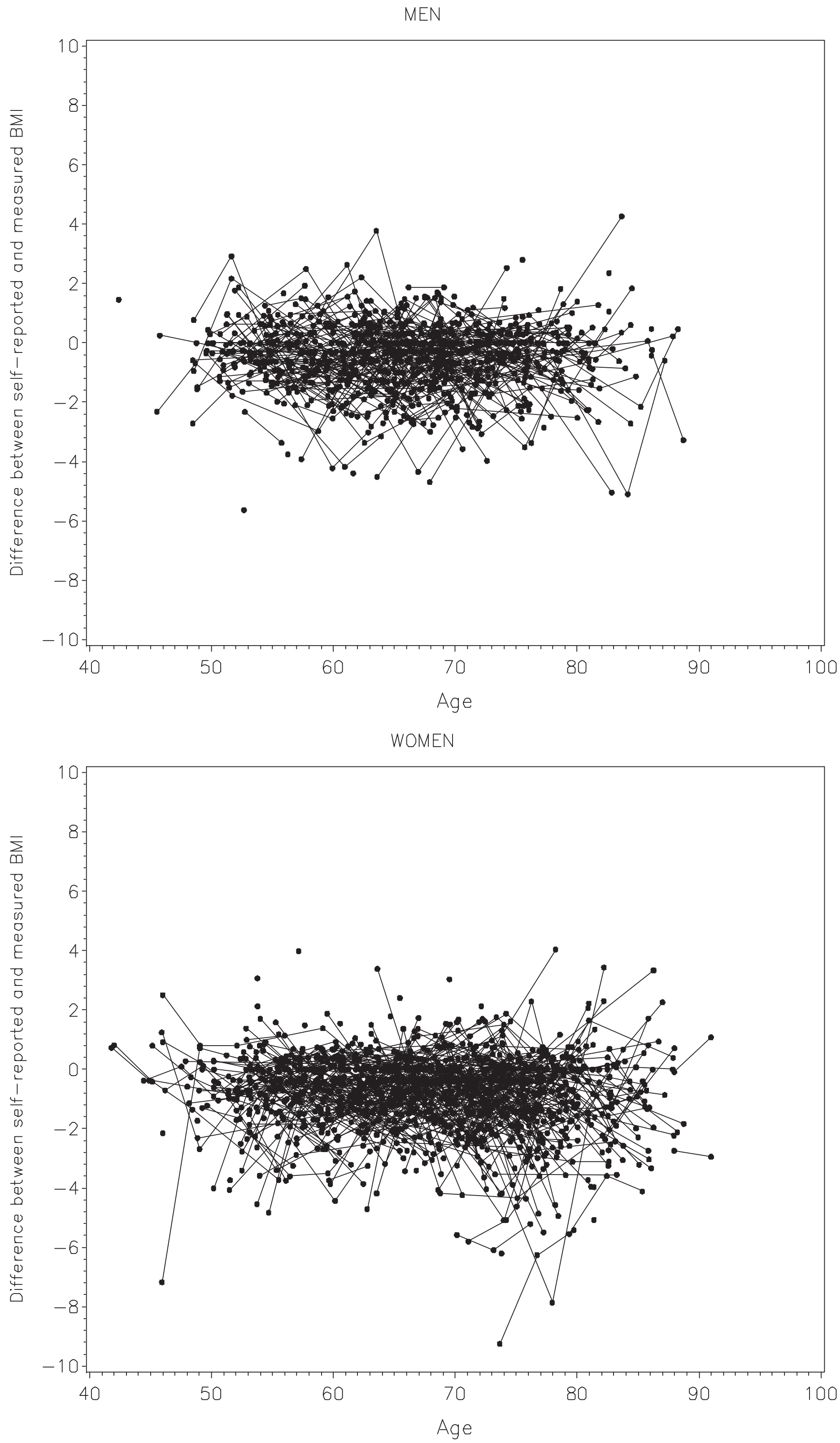

Figure 1. Longitudinal pathways of change in accuracy of self-reported BMI based on self-reported height and weight (self-reported BMI reduced by measured BMI). Each line represents a single person.

self-report tended to underestimate their weight by 0.7 kg ($P=0.10$) and BMI by 0.3 kg/m² ($P=0.11$) more than persons that first had their height and weight measured and then self-reported. There was no significant difference between the groups for height.

Analyses of outliers

For height, weight and BMI, persons above two SD were compared with persons within two SD, both quantitatively and qualitatively, to identify factors leading to under- and overestimation. There was no significant difference in prevalence of dementia between the outliers and persons within the normal range, as tested with Fisher's exact test. Some of the outliers had actually changed their weight substantially between two measurement occasions, and when the questionnaire came between these measurement occasions, it led to increased over- or underestimation of their weight. Some of the outliers seem to be due to transpositions in the report, i.e. a person self-reporting her/his height as 169 cm several times, but writing 196 cm on one occasion.

Discussion

To our knowledge, this is the first study evaluating the accuracy of self-reported height, weight and BMI longitudinally from midlife to late life. With increasing age, there is an increase in misclassification bias for height and BMI. However, this increase is hardly substantial, as the increase in misclassification bias over 20 years is smaller than at any single measurement occasion.

Height

It has been suggested in cross-sectional studies that the reliability of height is less valid in old age compared with young age [1, 2, 6, 7]. Our longitudinal study supports this notion, but indicates that the increase in misclassification bias is very small. Participants overestimate their height by a mean of ~1 cm; for each year this misclassification bias increased by 0.038 cm. Over 20 years, the increase in bias is <1 cm. Underestimation of height in old age is likely to be due to individuals reporting their height as measured in early adulthood and/or being unaware of changes in stature. More women than men overestimated their height in our study. This is similar to results from several other studies [1, 7], although some authors report no difference between genders [2], or that men showed greater overestimation [20]. Women are more prone to decreases in height than men, as they are at a higher risk of osteoporosis [21]. The prevalence of osteoporosis has been associated with increased overestimation of height in old age [4].

Weight

On average, participants underestimated their weight by 0.5–1.5 kg, and women were more likely than men to underreport their weight. Several cross-sectional studies [2, 6–8] indicate that the reliability of self-reported weight increases with age. Even though our results do not support that notion, our data show that the misclassification bias for weight does not increase over time, among both men and women.

BMI

Longitudinal analyses revealed that the difference between self-reported and assessed BMI increased with advancing age, in agreement with results from cross-sectional studies [1, 6, 7]. In contrast to these studies, we found that the increase in misclassification bias is small, ~0.016 kg/m^2 a year. Over 20 years, this results in an increase of BMI misclassification bias by 0.32 kg/m², which is less than the misclassification bias at any single measurement occasion. The change in accuracy of self-reported BMI was significant among the younger participants in the study, but not among the older participants. The lack of a significant change over time among the older participants is likely due to low statistical power. Only 14 of the persons born before 1920 had complete data from five measurement occasion.

Misclassification bias in BMI is mainly attributed to unawareness of changes in height and not in weight. Even though there are high correlations between self-reported and measured BMI over time and small mean difference between self-reported and assessed BMI, when BMI was used as a dichotomised variable, the prevalence of overweight and obesity was underestimated, as in other studies [1, 4, 6, 7, 22, 23]. Also in agreement with previous reports [2, 5–7, 24], persons with higher BMI scores underestimated their actual BMI to a greater extent than thinner persons. This indicates that social pressure to be slim also exists in old age.

Outliers

In the present sample there were some extreme outliers. Hypothetically, this could be attributed to a greater degree of dementia among these individuals. However, dementia did not affect the accuracy of self-reported BMI in this study or in the Canadian Study of Health and Aging [24]. This might be explained by the fact that there were only a few persons with dementia in the present study or that persons in their early stages of dementia might still remember their height and weight, while persons with severe dementia had dropped out from the study. Persons diagnosed with dementia might also report their weight as they remember it from earlier in life. As the normal trajectory of weight is towards weight gain over the early life span and weight loss in old age [25], a finding particularly true for persons with dementia, their actual present weight might be close to their weight during adulthood. Some of the outliers had actually changed their weight dramatically between the assessment and self-report, as indicated by later assessments. Other outliers were the result of writing errors, such as transposing numbers.

Strengths and limitations

The main strength of the present study is the longitudinal and population-based design. However, the longitudinal design might also skew results, as individuals recently seeing a health professional might provide more accurate information about body measures [8]. Although another study showed that recent measurements of height and weight did not really improve the reliability of self-reported values [20], people in the present study who had had their weight and height measured 3 months before the self-report tended to underestimate their weight and BMI less than the persons who were assessed after the self-report. Another limitation is the time span between the assessed and self-reported measures, ranging up to 1 year. On the other hand, we might underreport the reliability of weight. In SATSA, the participants' weight was assessed in clothes, but we believe that most people report their morning weight without clothes. Adding ~1 kg to the self-reported weight would remove most of the difference between self-reported and measured weight. As already discussed, some people also experienced substantial weight change during the time lag between the self-report and assessment, which contributes to an underestimation of the accuracy of self-reported weight and BMI. Given these potential sources of error, the mean difference in estimated and measured weight and BMI is quite small.

Key points

- There is significant and substantial agreement between self-reported and assessed height, weight and BMI in late life.
- There is a small increase in the mean difference between self-reported and measured BMI over time.
- The increase in misclassification bias for BMI is probably due to unawareness of changes in height.
- As the increase in misclassification bias for BMI is small, self-reported BMI can probably be used in longitudinal studies without affecting the results.
- There is no increase in misclassification bias for weight in old age.

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Conflicts of interest

None declared.

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Effects of dehydroepiandrosterone (DHEA) on cardiovascular risk factors in older women with frailty characteristics

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Abstract

Objective: this analysis was to investigate the effects of dehydroepiandrosterone (DHEA) on cardiovascular risk factors in older women with frailty characteristics.
Design, setting and participants: the study was a double-blind, randomised, placebo-controlled trial of 99 women (mean 76.6 ± 6.0 year) with the low DHEA-S level and frailty.
Intervention: participants received 50 mg/day DHEA or placebo for 6 months; all received calcium (1,000–1,200 mg/day diet) and supplement (combined) and cholecalciferol (1,000 IU/day). Women participated in 90-min twice weekly exercise regimens, either chair aerobics or yoga.
Main outcome measures: assessment of outcome variables included hormone levels (DHEA-S, oestradiol, oestrone, testosterone and sex hormone-binding globulin (SHBG)), lipid profiles (total cholesterol, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol and triglycerides), body composition measured by dual energy absorptiometry, glucose levels and blood pressure (BP).
Results: eighty-seven women (88%) completed 6 months of study; 88% were pre-frail demonstrating 1–2 frailty characteristics and 12% were frail with ≥3 characteristics. There were significant changes in all hormone levels including DHEA-S, oestradiol, oestrone and testosterone and a decline in SHBG levels in those taking DHEA supplements. In spite of changes in hormone levels, there were no significant changes in cardiovascular risk factors including lipid profiles, body or abdominal fat, fasting glucose or BP.